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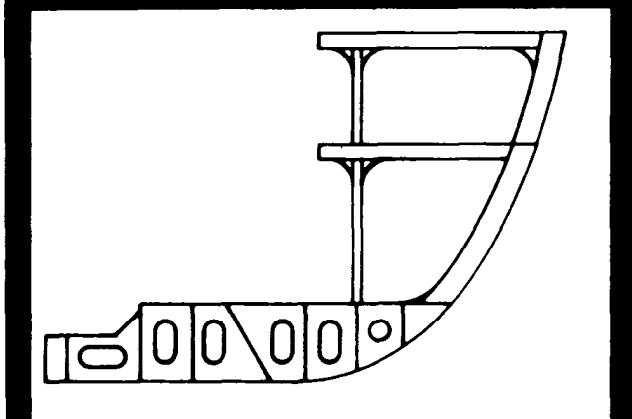
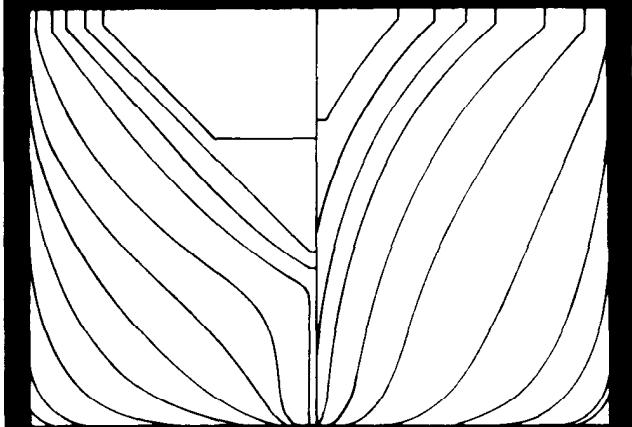
Paper No. 8: The Outfit Planning Problem

U.S. DEPARTMENT OF THE NAVY
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THE OUTFIT PLANNING PROGRAM*

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ABSTRACT

Shipbuilding as currently practiced in the U.S. commercial shipyards employs very little quantitative modeling or analysis in production planning. This paper presents a brief discussion of the shipbuilding process and focuses on one major component which is referred to as outfitting. The outfit planning problem is described in detail and then formally modeled as a generalization of the resource constrained project scheduling problem. The value of the approach as well as barriers to its adoption are also discussed.

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THE OUTFIT PLANNING PROBLEM

1. Introduction

Current practice in planning and scheduling ship production inherently limits the ability to integrate steel and outfit activities. It results in the bulk of outfitting work being performed in the erected hull, either on the ways, after a block is closed in, or at the wet dock or outfit pier. Working conditions in the hull are not ideal because of factors such as difficult access, limited space in which to work, difficulties in adequately venting noxious fumes, and difficult work positions (e.g., overhead welding). The workplace is typically congested, with high material flow costs, and often hazardous conditions.

It is now widely recognized that many of these problems can be relieved to some degree by doing more outfitting activities earlier in the production process, i.e., either in the assembly area or in the shop (vendor) area. To do this, however, requires a much greater integration of steel and outfit planning than has been the rule.

The fundamental problem is to identify economically desirable opportunities for preoutfitting. This requires answering two types of questions. The first is related to feasibility, i.e., "Is there sufficient time and resource available to do a particular outfitting activity in the assembly or shop area, and is it technically feasible?" The second question is one of economics, "Is it more economical to preoutfit the activity?" The answer to this question should take into account any limitations on outfitting resources. What is needed is a systematic way to answer these two questions.

2. PWBS and Z0FM

The Product-Oriented Work Breakdown Structure (PWBS) and the Zone Outfitting Method (Z0FM) are strategic approaches to ship production which have been proven effective through implementation in some of the world's most competitive shipyards. They are key elements in the drive toward better productivity, and there is little doubt that both will become widely-adopted (and hopefully adapted) by U.S. shipbuilders.

PWBS

The traditional definition of outfitting work packages (see, e.g., references 1 or 3) follows naturally from the systems-oriented design of the ship. This work breakdown is appropriate for design and estimating, and simplifies the collection of production data by system. Unfortunately, it also results in work packages which are too large and have too great a duration for truly effective control.

What is needed is a transition from the systems orientation necessary in design to a product orientation which is needed in production. Interestingly, this transition takes place almost instinctively in hull design and construction. PWBS provides a mechanism for also making this transition in outfitting.

PWBS divides the shipbuilding process into three basic types of work, hull construction, outfitting, and painting, and further classifies each type of work as fabrication or assembly. Interim products are classified by resource requirements and certain product features such as type of system (e.g., lighting system) and zone (any geographical division of the ship). It is noted that PWBS bears a close resemblance to group technology. It is quite flexible, and allows activities to be summarized in many different ways.

ZOFM

Zone outfitting is to outfit activities what hull block construction is to steel activities, i.e., it is a logical method for organizing the work to improve planning and productivity. Zone outfitting incorporates three stages for outfitting: on-unit, on-block, and on-board.

Outfitting on-unit refers to the assembly of an interim product consisting of only outfit materials. Examples are water distilling unit, fuel oil purifier unit, pipe passage unit, etc. Outfitting on-unit impacts the shop-related resources and the material handling facilities. It may require additional labor and materials for structural support to units to permit their movement to the assembly or ways areas. It also has some impact on hull construction progress since the unit must be landed. However, "on-unit outfitting should be given the highest priority . . . because assembly is performed in shops which provide ideal climate, lighting, and access" (see reference 2).

Outfitting on-block refers to the installation of outfit components, or units, in a hull block in the assembly area prior to its erection on the ways. Outfitting on-block is more difficult than outfitting on-unit because it requires careful coordination between the steel activities and the outfit activities and may impact the duration of a block's occupation of an assembly area.

Outfitting on-board includes any required outfitting activity which has not been performed in either of the two previous stages. Although outfitting on-board describes outfitting as usually practiced, it also allows for nontraditional activities such as the connection of outfit units or outfitted blocks.

3. The Outfit Planning Problem

Because zone outfitting defines various stages for outfitting, it admits alternatives for the execution of outfit activities. Thus, the full exploitation of the zone outfitting concept requires that production management be able to resolve all the alternative choices available. The problem of resolving the alternatives and defining a single outfit plan is referred to here as the outfit planning problem. In order to explore the problem in more detail, it is helpful to classify outfit elements according to the outfitting options which may be applied.

There are some outfit components which are only installed in the on-board stage, e.g., furnishings and other similar materials which are subject to damage or pilferage are always installed in the on-board mode. These will be designated on-board components. Of the remaining components, some are associated with distributed systems, e.g., wireways or ventilation ducting, rather than with distinct units, e.g., pumps, motors, valves, etc. These will be referred to as non-unit components, since outfitting on-unit is not appropriate. Finally, there are the outfit components which could be identified by or associated with a specific unit. These will be referred to as free components, since they may be installed in any of the three modes. (Note that it is usually desirable to outfit on-unit whenever possible, but it is conceivable that resource limitations might dictate otherwise.)

The designations on-board, non-unit, and free are fixed to some extent by design practices. For example, a given group of outfit components, say a pump and piping, may be conceived and designed in several ways. If it is treated simply as a collection of separate components which must be installed in the ship, then the components will have the non-unit designation.

Alternatively, if the components are viewed as integral parts of a single unit or set of units, then they will have the free designation. Chirillo and Jonson (reference 2) give examples of outfit components that could be associated with units, although they typically are not in U.S. shipyards. Figure 1 illustrates the relationships between the designations and the associated production facilities.

Outfit planning requires, for each outfit component, a selection of outfit mode. The selection decisions are constrained by a number of factors. In particular, it is common practice to take the hull block erection schedule as fixed when planning the outfit activities. For example, each hull block has a fixed deadline for its completion, and at that point in time it is lifted onto the ways for erection. Thus, all on-block outfitting planned for that hull block must be completed before its erection date. Similarly, if a unit is to be installed in the block, all the associated on-unit outfitting must be completed in time to allow the unit to be moved onto the block and installed before the block erection date. Furthermore, if the block closes in any previously erected blocks, any large components (main engine, diesel generators, etc.) must be landed in these blocks prior to closing in.

The hull block erection schedule is a constraint in outfit planning because of convention. It is also possible to treat the hull block erection schedule as part of the decision process, i.e., if it were justifiable, a hull block might remain in the assembly area longer to allow more on-block outfitting to be performed.

Another constraint which may affect outfit planning decisions in many yards is the available lifting capacity. Outfit units and outfitted hull

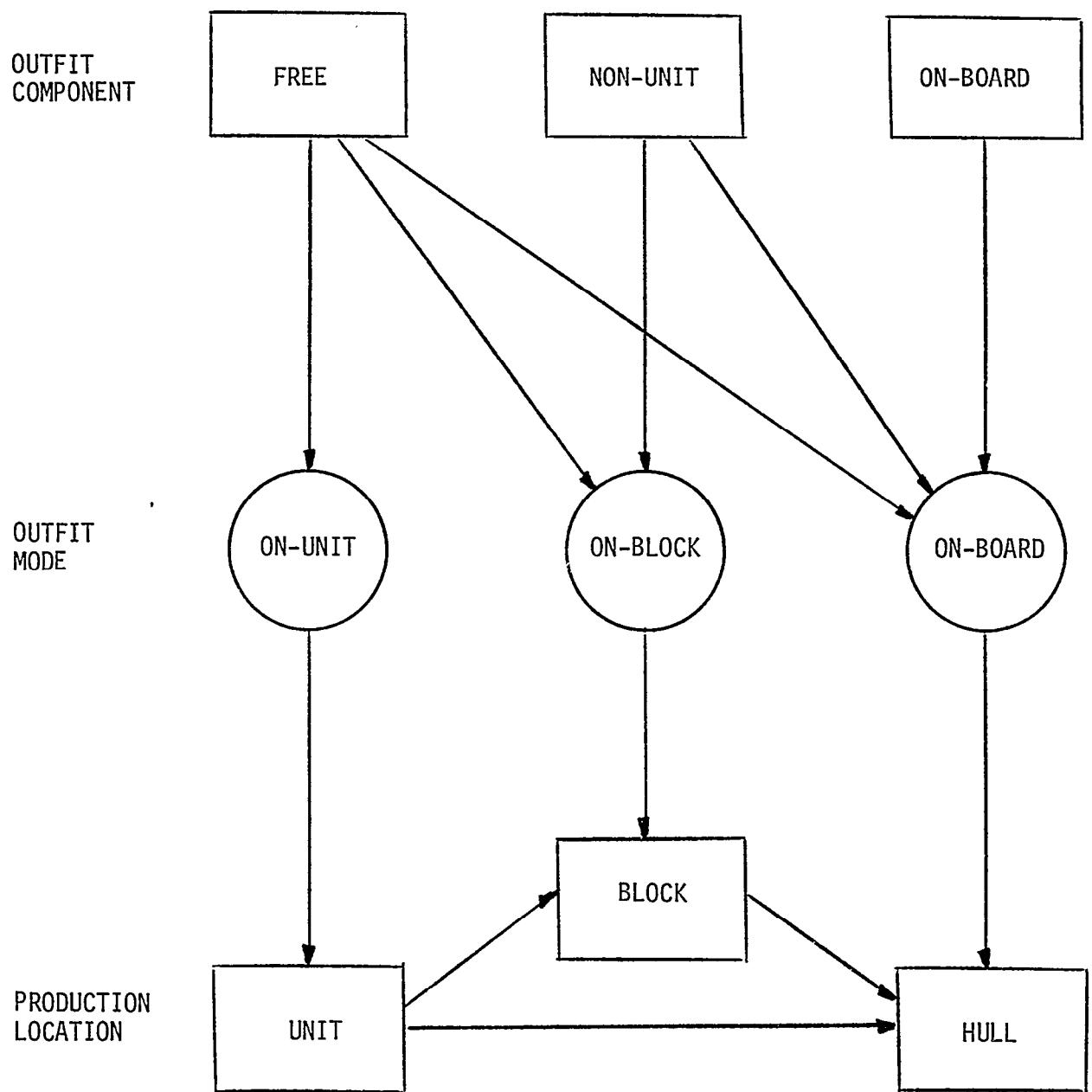


FIGURE 1 Relationships Between Outfit Components, Outfit Mode and Production Location

blocks must not exceed the safe lifting capacity of the available equipment. Size is a similar consideration, i.e., units must be sized in light of the available access.

The effect of outfit planning decisions on limited yard resources must also be considered. Among the resources which are affected are labor and material availability and production or storage space. When determining outfit mode, care is required to insure that the resulting production schedule does not call for more labor than is available in each affected craft and grade. Likewise, since production typically requires space and fabricated components or units may need to be stored temporarily, the available yard facilities must not be overcommitted.

These resource allocation considerations are perhaps the most difficult aspect of outfit planning, especially in situations where multiple ships are in production simultaneously. The reason is that in order to guarantee feasibility of the mode selections, a feasible schedule must be determined. The selection decisions and subsequent scheduling decisions interact in a complex fashion and cannot be made independently.

Considerable cost savings are indicated (see, e.g., references 2 and 3) for outfitting on-unit and on-block instead of on-board. These cost savings result from lower skill requirements, better material access, less congestion, better quality control, etc. Another result of increased on-unit and on-block outfitting would be reduced delivery time. Reducing delivery time is favorable to both owner and builder, since the owner has use of his ship sooner and the builder receives final payment sooner. In addition, the owner benefits from the reduced ". . . interest costs for the substantial accumulating investment represented by construction progress and for achieving

ing maximum utilization of expensive facilities such as a building dock" (reference 2).

Thus, two goals to strive for in making the outfit planning decisions are to minimize outfitting costs and to minimize the completion time for the ship. In particular circumstances, other goals might be relevant.

The outfit planning problem can now be stated more precisely as follows:

Given: (1) a catalog of the outfit elements for which there are outfit mode options,

(2) for each such element, a list of the outfitting mode options, including time, resource and precedence requirements,

(3) the key events schedule and possibly the hull block erection schedule,

(4) outfit labor availability by craft and grade,

(5) outfit facility capacities and availabilities,

(6) other constraining factors, such as material availability, rate of cost accumulation, etc. ,

Determine: The outfitting mode to be used for each outfit element and the specification of the associated work packages, along with the associated production schedule.

4. A Decision Support System

The traditional approach to outfit planning can easily result in 2500 outfitting work packages, each requiring between 200 and 2000 manhours, and having durations of 3 months or more. The full adoption of PWBS and ZOFM will lead to a larger number of more tightly defined work packages. Current practice typically has one individual responsible for outfit planning. Clearly, one individual using only manual techniques can not adequately consider, for so many elements, the range of outfit mode options that are possible with ZOFM.

A system is needed for helping the outfit planner cope with the multitude of outfit elements, outfit mode options, and resulting outfit work packages. Such a system would need to be computer oriented for most large scale applications, and would need access to a reasonably detailed production data base, such as the SPARDIS system developed by NAASCO (see reference 4).

A well designed decision support system (or DSS) would have several important features. It would be useful not only for initial planning and scheduling, but would also be capable of replanning and rescheduling in response to major unforeseen events (strikes, material shortages, rush jobs, facility problems, etc.) or simply accumulated deviations from the original plan. Thus, the system must use both engineering standards and other planning data, and actual production progress or status data.

The DSS should recommend outfit mode selection and work package scheduling decisions, and should allow the outfit planner to override these recommendations. Note this means that the DSS must incorporate some technique for solving the outfit planning problem as stated in the previous section.

Finally, the DSS should be interactive, so that the outfit planner can use the system without needing either computer expertise or a computer programmer to act as the interface. Figure 2 summarizes these requirements in an overview fashion. The important features shown in the figure are: (1) the human is always the key component in the process, and (2) the process can be iterative. The outfit planner may look at several solutions before he releases one to production. Also, the process can be repeated as many times as necessary.

The commercial development of a DSS for outfit planning requires first of all a large effort in data base design and implementation. The techniques required, however, are all well known. Obviously, the system should incorporate needed elements from PWBS and ZOFM. There remains one element of the system for which there are no readily available techniques. This is the element concerned with solving the outfit planning problem in order to recommend solutions to the outfit planner.

A formal mathematical model of the outfit planning problem has been developed and is described in detail in reference 4. Based on this mathematical model, a solution procedure has been designed and is currently being implemented in experimental software. Also, a testbed problem is being developed, based on actual outfit data from a current ship production project. Results of exercising the solution procedure on the testbed problem will be reported on in the near future. Interested readers may contact the authors for further details.

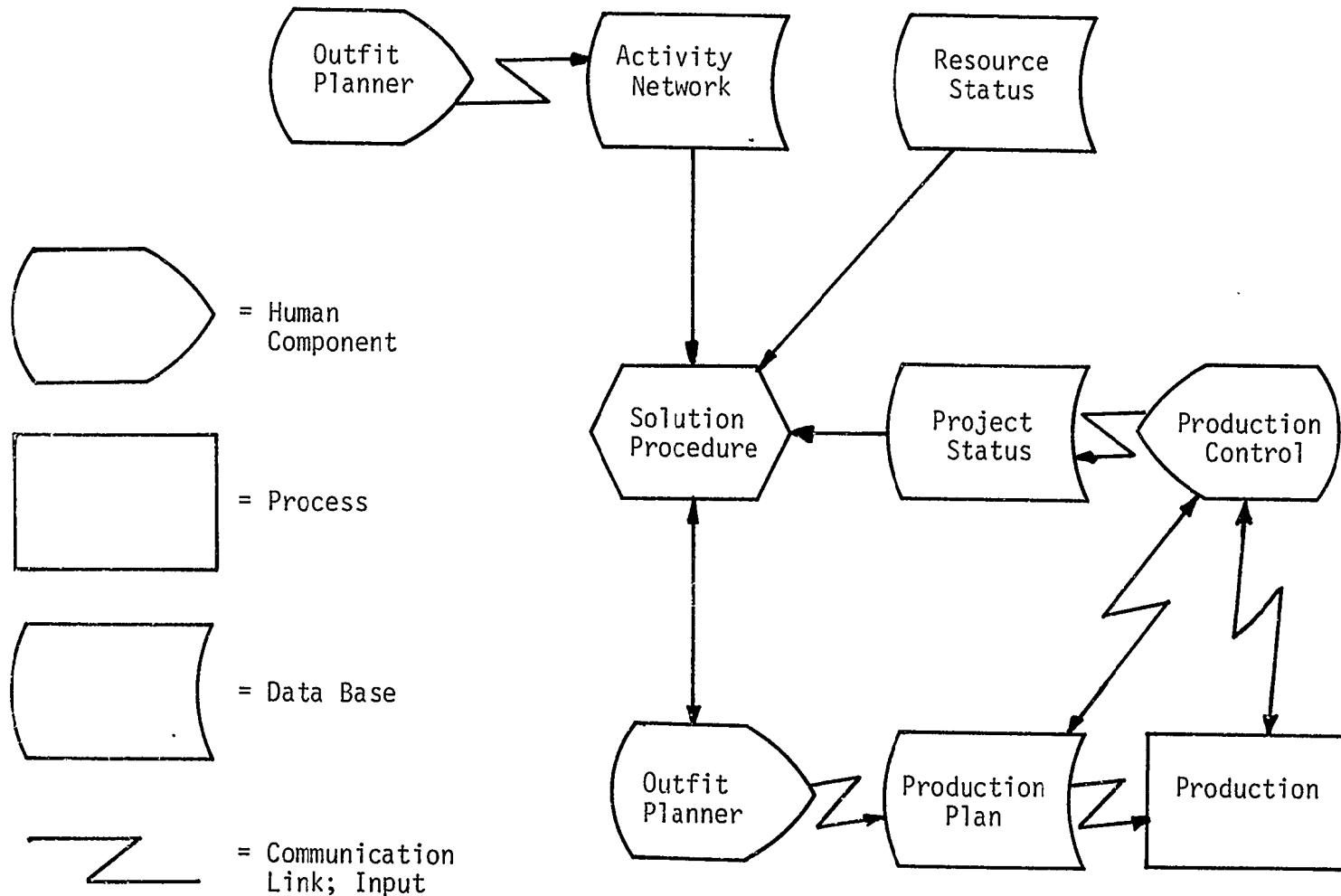


Figure 2 Outfit Planning Process

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